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Semi-Annual Status Report

for

NASA Grant NGR 43-001-135

**PROGRAM TO STIMULATE GRADUATE TRAINING
IN THE FIELD OF AEROACOUSTICS**

March 1, 1975 - September 1, 1975

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INTRODUCTION

Under NASA Grant NGR-43-001-135, The University of Tennessee Space Institute is engaged in a program to stimulate graduate training in the field of aeroacoustics. A Ph.D. candidate, Mr. Robert S. Becker, will be supported for three years of academic and research training at The University of Tennessee Space Institute, including up to one year of research in the facilities at the NASA Lewis Research Center. This report is a status report covering the fourth six-month period of this program.

LOGISTICAL PREPARATIONS FOR THE CROSS-CORRELATION EXPERIMENT TO BE PERFORMED AT LEWIS CENTER

During this reporting period, logistical support for the U.T.S.I. cross-correlation experiment, to be performed in December of this year, was arranged by the student investigator and Lewis Center personnel. In this experiment, the output of a hot film probe, located at various points in the flow field of a jet-blown flap, will be cross correlated with the output of a microphone in the acoustic far-field, in an attempt to establish a causal relationship. Equipment needs and specifications were defined and fabrication of long lead-time items commenced early in summer. In particular, a ten inch plenum chamber and transition piece for slot nozzles will be made for the experiment by Lewis Center. This chamber and transition piece will duplicate the facility at U.T.S.I. Also, orders for hot-film probes were placed with the manufacturer, and the need for engineering support to develop a reliable and accurate hot-film probe traversing system was discussed.

FLUID DYNAMIC MEASUREMENTS

In preparation for the cross-correlation experiment to be performed at Lewis Center, an investigation of the flow field of the test configuration was made. This configuration consisted of a slot nozzle (height = 5 mm, length = 135 mm, aspect ratio = 27) with an attached 2 inch flap. The test was conducted using the new indoor test facility at U.T.S.I which was described in the last progress report. The exit Mach number of the flow was .9, which corresponded to a velocity of 970 ft/sec for the test conditions. A hot-film probe was used to measure the mean velocity and the r.m.s. value of the velocity fluctuations of the flow. By suitably processing the hot-film signal, the frequency spectrum and autocorrelation coefficient of the fluctuating velocity was obtained. Figure 1 shows a schematic of the experimental set-up.

In order to obtain profiles of the mean velocity and the r.m.s. value of the velocity fluctuations (turbulence intensity), a probe traverse using a slaved stepper-motor was used to sweep the flow field at various downstream stations. The profiles of the mean velocity and turbulence intensity for each of these stations is plotted simultaneously on a pair of x-y plotters. Six of the mean velocity profiles and the corresponding turbulence intensity profiles are displayed in Figures 2 and 3 respectively. These profiles were all taken at stations aft of the flap trailing edge. The flow field forward of the flap trailing edge has also been measured, but it is the aft area that has the most interesting flow features. Schecker (1) explored the secondary mixing region aft of the flap trailing

edge. In a hot wire investigation of the incompressible flow field of a jet-flap configuration, he found the turbulence of the secondary mixing region to be greater than that of the primary mixing region (see figure 4). Schecker surmised that this secondary mixing region was a principle source of aerodynamic noise in jet-flap flow, at least as strong as the primary mixing region.

The dominance of the secondary mixing region as a region of high turbulence intensity is confirmed for subsonic compressible flows as well. Figure 3 clearly shows this dominance. The profile at $x/h = 10.2$ was taken at a downstream station very close to the flap trailing edge. The trailing edge is located at $x/h = 10.16$. The peak to the right of the origin is the secondary mixing region. At this station, the spatial extent of the secondary mixing region is $.624 h$ or 3.12 mm . The corresponding mean velocity profile in Figure 2 shows a very large gradient as the probe enters the flow region above the plane of the flap. The remainder of the profiles shown in Figures 2 and 3 show the behavior of the flow at various downstream stations. The trend to be noted in the turbulence intensity profiles is the diffusion of the secondary mixing region. In the profile taken at a downstream station corresponding to $x/h = 20$ it can be seen that while the secondary region is still dominant, the trend toward symmetry is clear. The distance between the first station and the last station is approximately one flap length (2 inches). In the mean velocity profiles, this diffusion process can be seen to reduce the mean velocity gradient in the secondary mixing region. The trend toward

symmetry is again evident. A better indication of the highly turbulent nature of the secondary mixing region can be observed when the turbulence intensity is normalized by the local mean velocity. Figure 5 is a plot of the normalized turbulence intensity for 3 downstream stations. It is in the region of high turbulence intensity and high mean velocity gradient that significant aerodynamic noise production is expected. It is hoped that the cross-correlation technique can resolve the contribution of this area to the overall aerodynamic noise produced by the entire flow field.

Hot film signals at various points in the flow field were autocorrelated and spectrum analyzed. Figures 6 and 7 are representative of the results. Figure 6 is a spectrogram of the linearized hot film signal from a probe located at a point corresponding to $x/h = 10.5$, $y/h = 0.0$. The spectrogram shows a discrete component between 6000 and 7000 Hz. Processing the hot film signal through a digital correlator shows clearly the strong periodic component in the probe signal, as seen in Figure 7. The period of the autocorrelation function is seen to be 150 microseconds corresponding to a frequency of 6666 Hz. This periodic disturbance is seen at other points aft of the trailing edge of the flap, and the sound generated by the flow has a very strong tone component of the same frequency.

Flow shadowgraphs of the trailing edge region reveal what seems to be vortex shedding from the flap trailing edge. It appears that this phenomenon occurs when the potential core length is approximately the same as that of the flap. Because of this observed large scale phenomenon, it was decided not to use the two inch flap for the cross-correlation experiment at

Lewis Center. A longer flap will be used in order to avoid the creation of large scale disturbances.

REFERENCES

1. Schecker, G. O., "Turbulence and Aerodynamic Noise Characteristics of Jet Flap Type Exhaust Flows", Ph. D. Dissertation, The University of Tennessee, Knoxville, Tennessee, 1972.

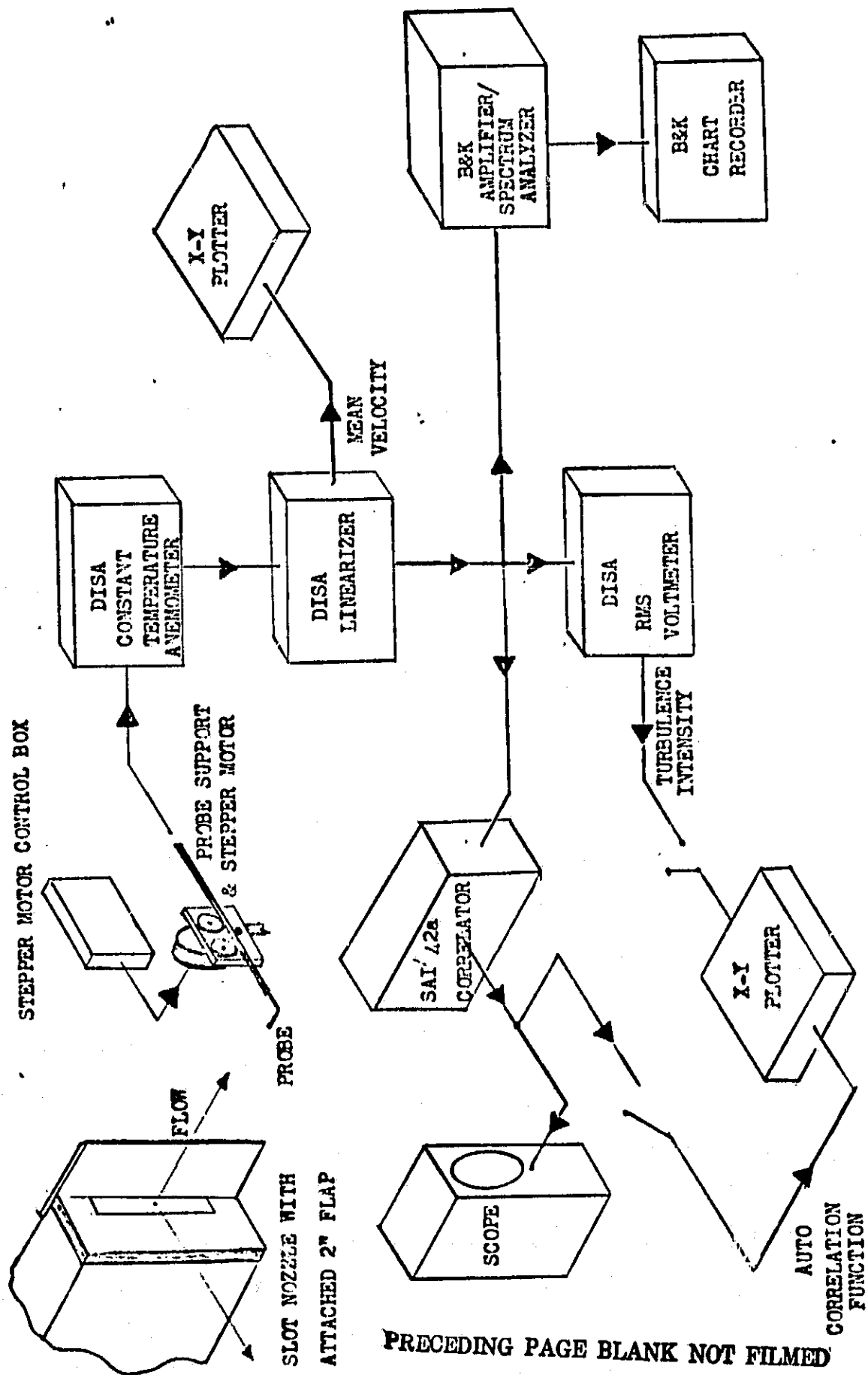


Figure 1 Schematic of Experimental Set-up

MEAN VELOCITY, FT/SEC X 100

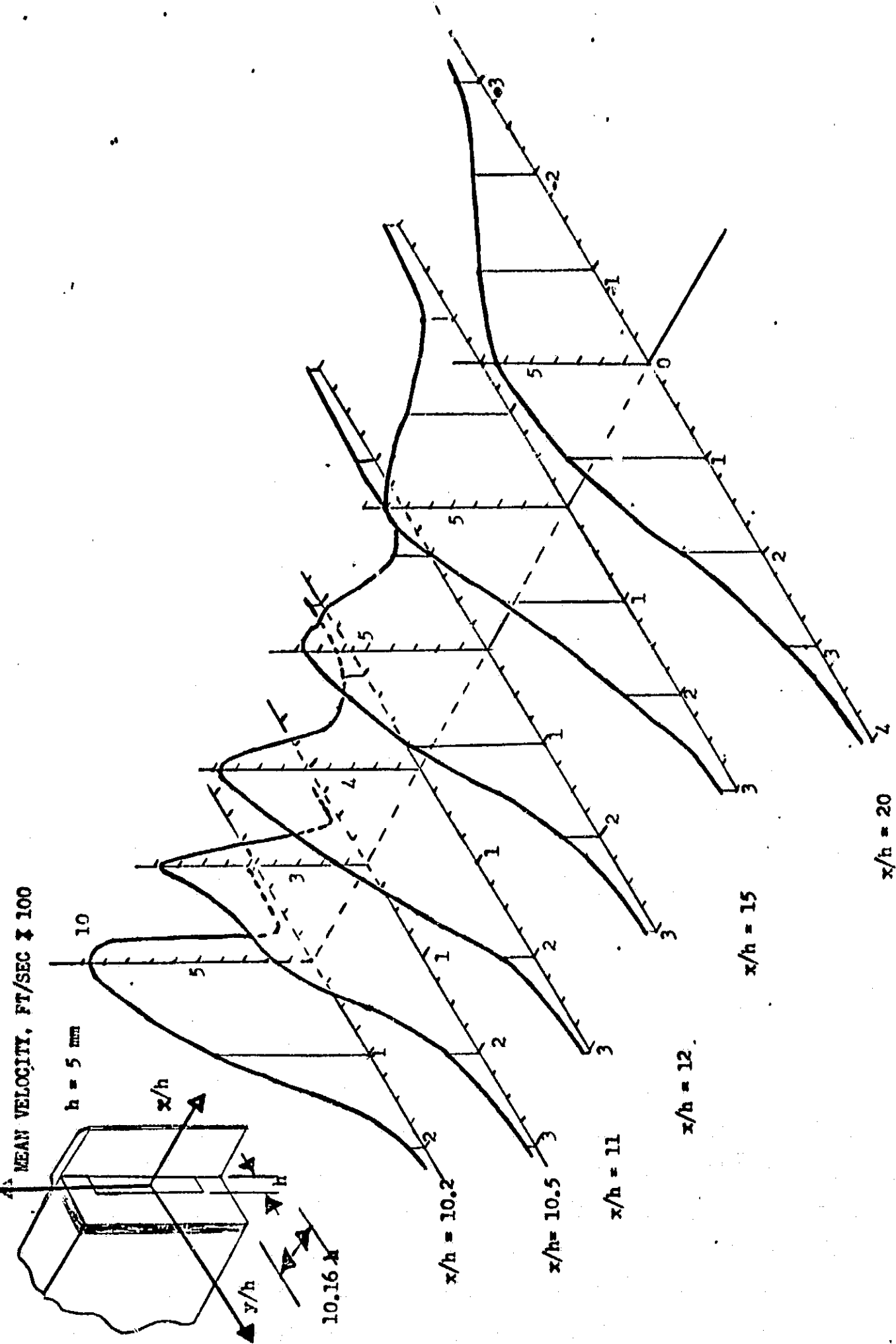


Figure 2 Mean Velocity Profiles

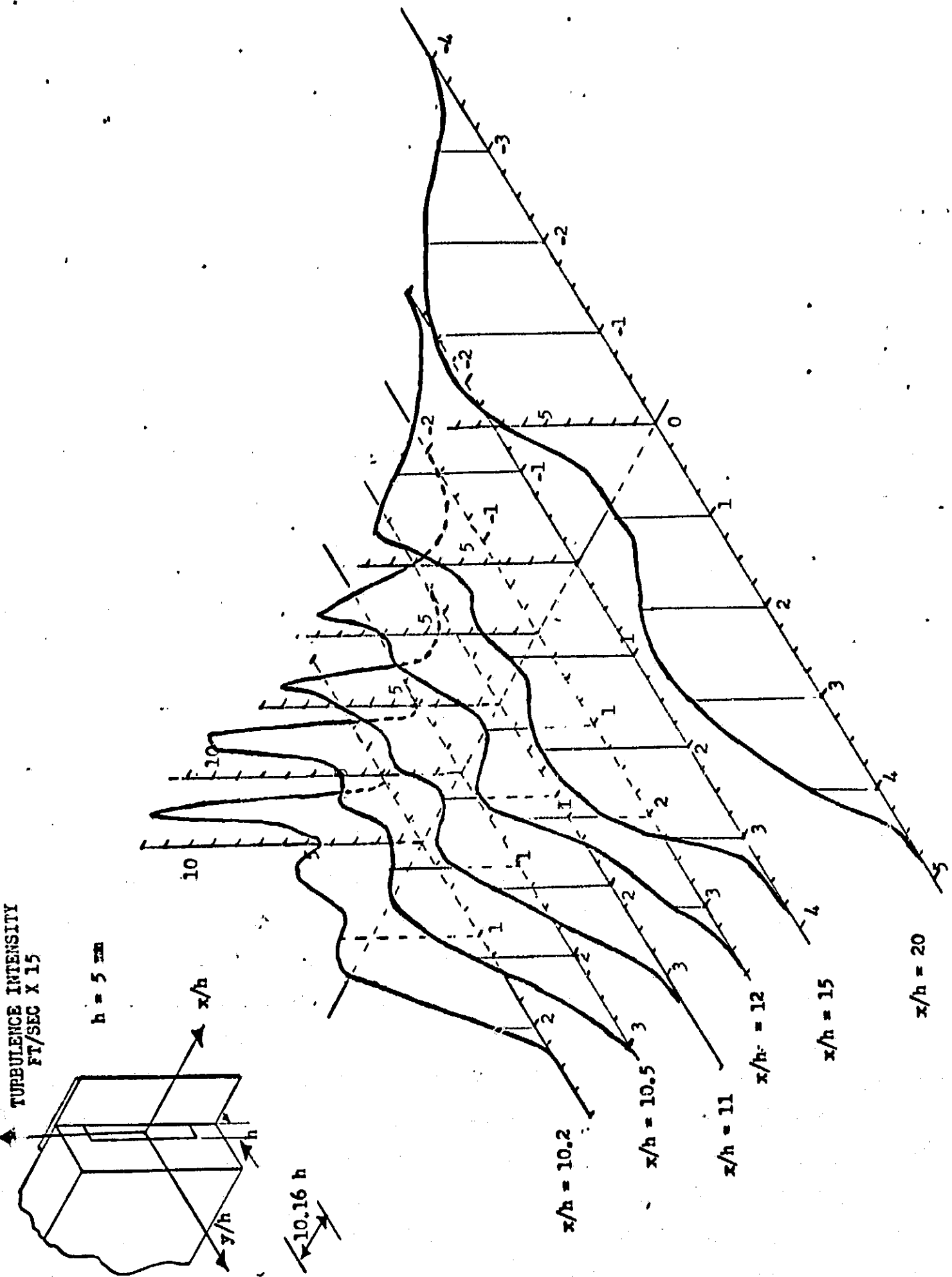


Figure 3 Turbulence Intensity Profiles

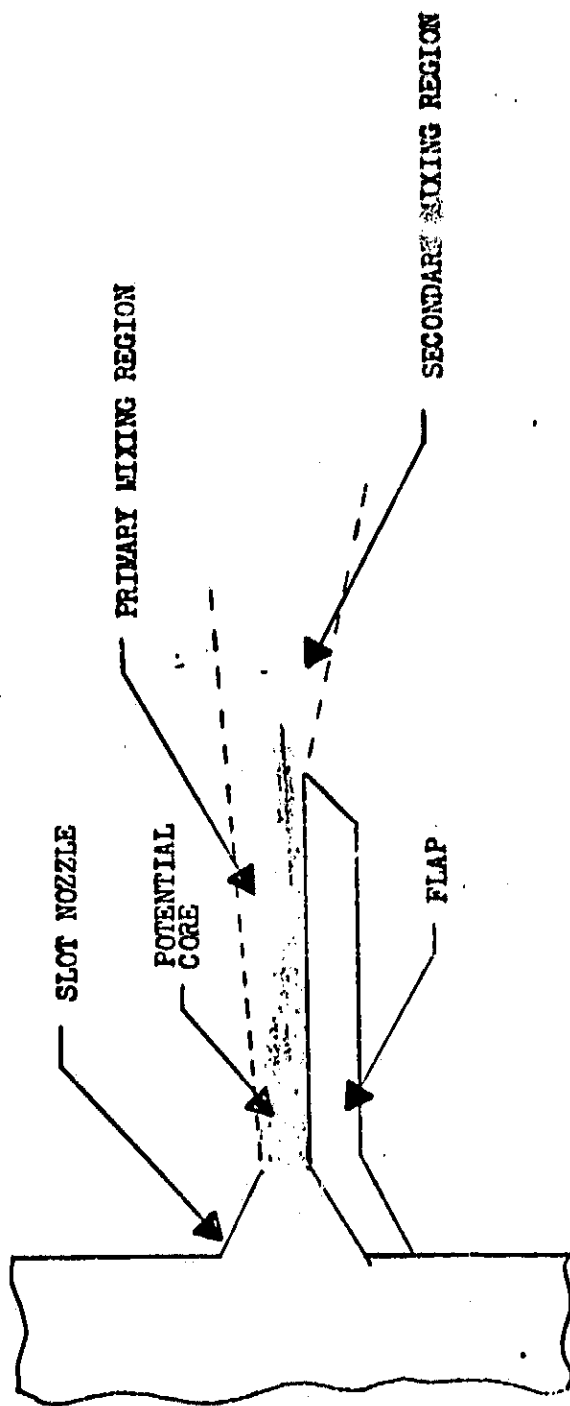


Figure 4 Flow Regions of the Jet -Flap Configuration

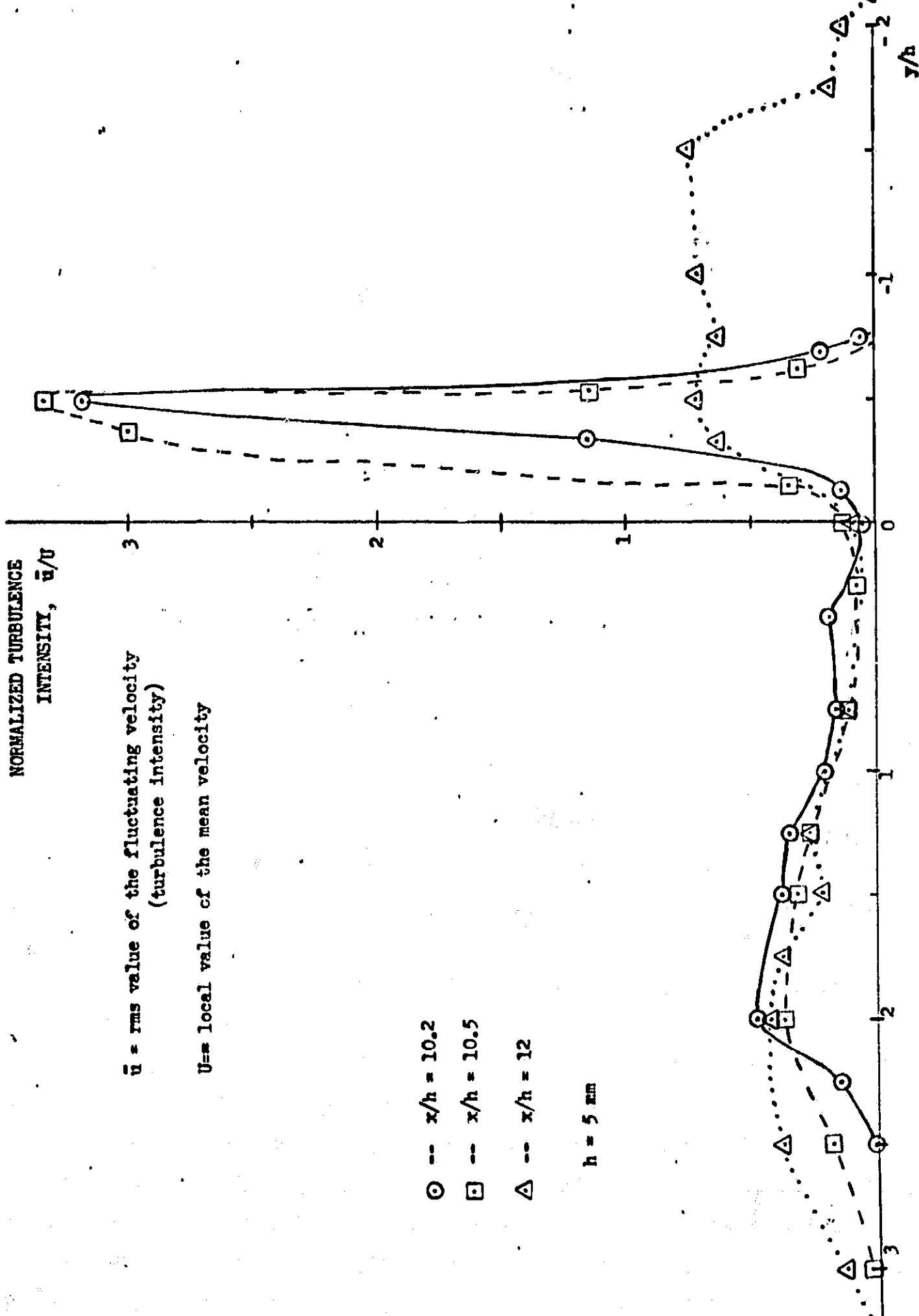


Figure 5 Normalized Turbulence Intensity

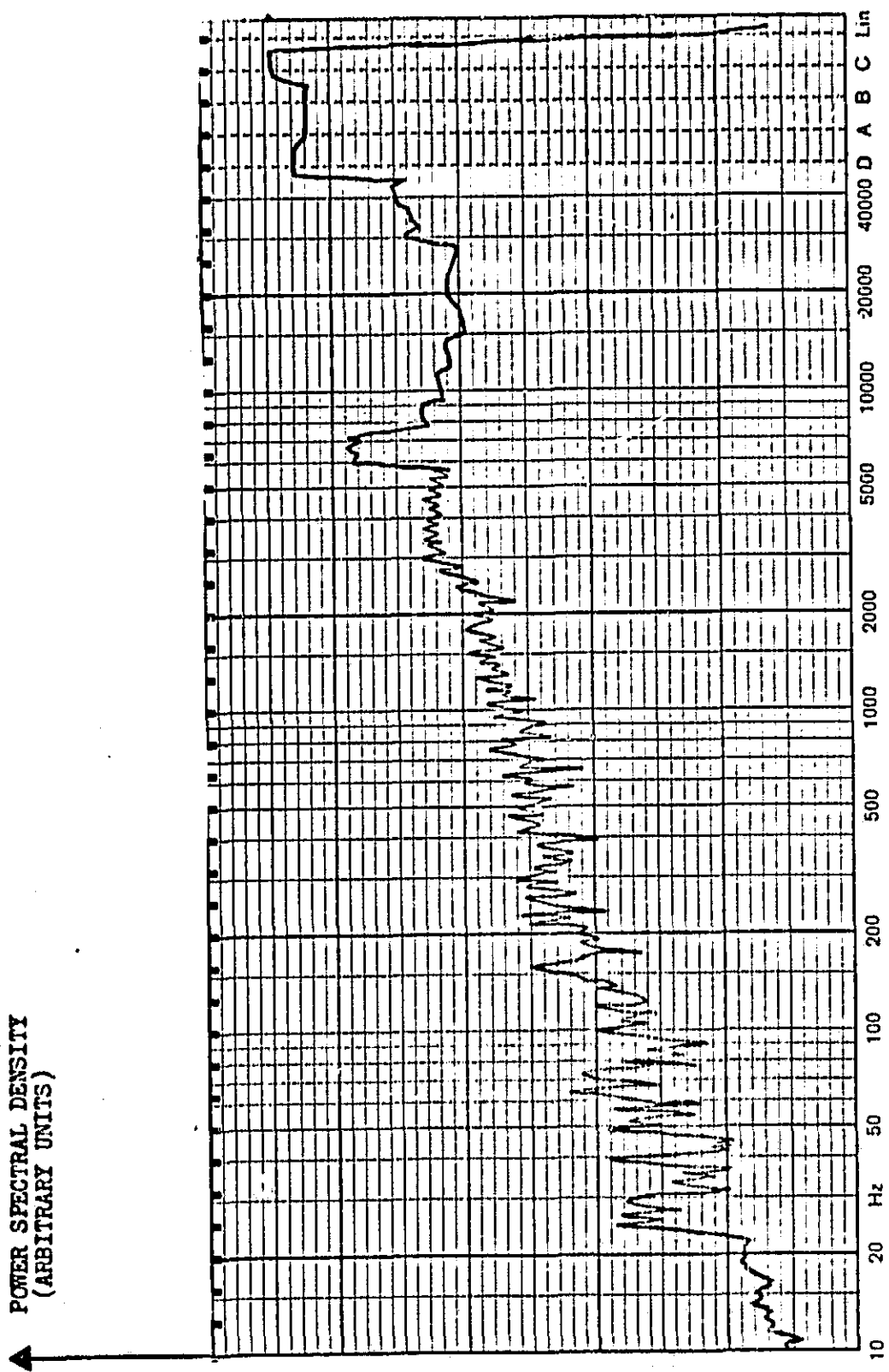


Figure 6 Spectrogram of Hot Film Probe

$$x/h = 10.5 \quad y/h = 0.0$$

$R_{vv}(\tau)$
ARBITRARY UNITS

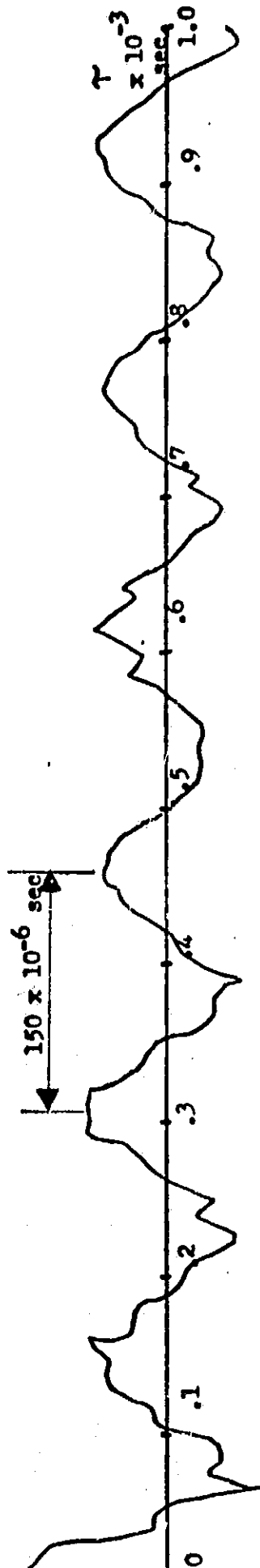


Figure 7 Autocorrelation of Hot Film Signal

$x/h = 10.5$ $y/h = 0.0$